IS 10853-2 (1984): Methods of measurement for radio transmitters, Part 2: Frequency [LITD 12: Transmitting Equipment for Radio Communication]

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Indian Standard

METHODS OF MEASUREMENTS FOR RADIO TRANSMITTERS

PART 2 FREQUENCY

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INDIAN STANDARDS INSTITUTION
MANAK BHAVAN, 9 BAHADUR SHAH ZAFAR MARG
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METHODS OF MEASUREMENTS FOR RADIO TRANSMITTERS

PART 2 FREQUENCY

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Indian Standard

METHODS OF MEASUREMENTS FOR RADIO TRANSMITTERS

PART 2 FREQUENCY

0. FOREWORD

0.1 This Indian Standard (Part 2) was adopted by the Indian Standards Institution on 31 January 1984, after the draft finalized by the Radio Communications Sectional Committee, had been approved by the Electronics and Telecommunication Division Council.

0.2 The object of this standard is to standardize the conditions and methods of measurements to be used to ascertain the performance of a radio transmitter and to make possible the comparison of the results of measurements made by different observors.

0.3 This standard is one of a series of standards on methods of measurement for assessing the performance of radio transmitters for various classes of emission and covers measurements for parameters relating to frequency. Other characteristics likely to be covered in this series are:

a) General conditions of measurements;

b) Output power and power consumption;

c) Band-width, out of band-power;

d) Power of non-essential ossilations;

e) Wanted and unwanted modulation;

f) Amplitude/frequency characteristics and non-linearity distortion in transmitters for radio-telephony and sound broadcasting;

g) Measurements particular to transmitters and transpowers for monochrome and colour television;

h) Cabinet radiation at frequencies between 130 kHz and 1 GHz;

j) Cabinet radiation at frequencies above 1 GHz;

k) Vestigial sideband demodulators for use in conjunction with transmitters or transposers for monochrome or colour television; and

m) Transposers for monochrome and colour television.

0.4 This standard is largely based on IEC Pub 244-1 (1968) 'Methods of measurement for radio transmitters: Part 1 General conditions of measurement, frequency output power and power consumption', issued by the International Electrotechnical Commission (IEC).

0.5 In reporting the results of a test or analysis made in accordance with this standard, if the final value, observed or calculated, is to be rounded off, it shall be done in accordance with IS : 2-1960*.

1. SCOPE

1.1 This standard (Part 2) lays down the methods of measurement of characteristics relating to frequency as applicable to radio transmitters for all classes of emission.

1.2 This standard shall be read in conjunction with IS : 10853 (Part 1)-1984†.

2. GENERAL

2.1 From the point of view of an effective use of the radio-frequency spectrum and with respect to reducing mutual interference caused by radio services occupying adjacement channels, departures from the frequency assigned to radio transmitter should be kept within acceptable limits, in accordance with radio regulations. The centre frequency of the frequency band assigned to an emission of a radio transmitter is called "assigned frequency". For particular classes of emission, for example single-sideband emissions with full, reduced or suppressed carrier, the centre frequency of the occupied band that should correspond with the assigned frequency may be difficult to identify or not even be present at all. Therefore, a frequency that is referred to as "reference frequency", is chosen. Such a reference frequency has a fixed and specified position with respect to the assigned frequency, for example the frequency of the reduced carrier of a single-sideband emission.

2.2 Frequency Tolerance and Frequency Error — In practice, the reference frequency is hardly ever met exactly by a transmitter. The operating frequency which is intended to be set to coincide with the reference frequency by choosing the desired piezoelectric crystal, or by setting the calibrated scale of the frequency determining oscillator of the transmitter to the desired position, has inevitably a setting error against the reference frequency.

*Rules for rounding off numerical values (*revised*).

†Methods of measurements for radio transmitters ; Part 1 General conditions of measurements.

2.2.1 Moreover, the operating frequency is not constant; the operating frequency which is called chacteristic frequency in conformity with the terminology used in the Radio Regulations, varies due to changes of operating conditions, such as:

a) cyclic variations, diurnal or seasonal, of the environmental conditions (temperature, humidity and air pressure), affecting the crystal and/or oscillator circuits;

b) variations of primary power supply voltage and frequency;

c) jumps in frequency caused by vibration or mechanical shocks, inherent in the use of the equipment;

and to other influences, for example.

d) valuations of temperature in the oven due to the operating cycle of the thermostat; and

e) drifts due to ageing processes in the crystal and/or the oscillator circuits.

2.2.2 The difference between the reference frequency and the characteristic frequency is the 'frequency error' which is never to exceed the specified frequency tolerance.

2.3 Frequency Stability and Frequency Variation — While the frequency tolerances indicated in the radio regulations are based on considerations of spectrum economy and the prevention of interference, the frequency difference during a given communication period which may arise between transmitter and receiver is of interest from the user's point of view. In order to prevent the transmitted information from being deteriorated in an unacceptable measure, the frequency difference occurring in a complete system is not to exceed, at least during a certain period, a value that depends on the class of emission and the service to be provided.

NOTE — From the user's point of view, in an amplitude-modulated double-sideband telephony emission with full carrier, there might be no objection to a departure of the carrier frequency of, for example, 100 Hz from the value of the beginning of the communication period. However, for a suppressed carrier emission, a departure of 100 Hz may be troublesome whilst for, for example, a frequency-shift emission with a frequency shift of 170 Hz, a frequency variation of 100 Hz is definitely objectionable, notwithstanding the fact that the frequency tolerance given in the Radio Regulations might be 300 Hz for the three classes of emission considered.

2.3.1 The difference between the highest and the lowest value of the characteristic frequency during a given period to the transmitting equipment is called the frequency variation of the transmitter. For the variations of operating conditions that may be expected during that given period, the frequency variation is not to exceed the limits given by the frequency stability quoted in the relevant equipment specification, which limits must never be wider than those of the frequency tolerance.

3. MEASUREMENT OF THE CHARACTERISTIC FREQUENCY OF AN EMISSION

3.1 The characteristic frequency may be measured with any suitable measuring device, provided that the accuracy attained during the measurement is better than approximately 10 percent of the ferquency tolerance or the frequency stability given in the relevant equipment specification of the transmitter.

3.1.1 For a tight frequency tolerance or a high degree of frequency stability, the measuring accuracy stated above may be put high demands on the accuracy of the measuring apparatus which, in practice, may not always be met. In such cases satisfactory results may be obtained by treating statistically a number of rapidly repeated measurements.

3.1.2 Other methods of great precision use a standard reference oscillation, the frequency of which is known with high accuracy. With such methods the transmissions of standard frequency stations may be used to advantage.

3.1.3 When the frequency is to be measured as a function of time measurements shall be made at intervals short enough to reveal the presence of superimposed periodical variations. In this case, the measurements shall preferably be made with a recording instrument.

NOTE — The rate of frequency variation as recorded depends on the ballistic characteristics of the instrument. These characteristics shall be such that the magnitude of the deflection of the instrument will not be influenced at the fastest rate of frequency variation to be expected.

3.1.4 The accuracy of the measuring method or, if not known, an estimation of the accuracy shall be stated with the results of the measurements.

3.1.5 The conditions of operation shall be given as well, together with the frequency on the emission which has been used as the characteristic frequency.

4. MEASUREMENTS DURING THE INITIAL PERIOD OF FREQUENCY VARIATION OF A TRANSMITTER

4.1 The various characteristics shall be determined from the results of a series of measurements of the characteristic frequency according to 3.

4.1.1 After the equipment has been switched off during a sufficiently long period, the measurements shall be started under the specified conditions of operation immediately after switching-on and be continued until the frequency remains permanently within the limits given by the frequency tolerance of the transmitter. The characteristic frequency may be measured with a recording instrument or be plotted in a graph. From

this graph the initial period of frequency variation may be derived, as well as the initial frequency variation and the initial frequency error.

4.1.2 Even though the period during which the frequency error exceeds the frequency tolerance may be small, care shall be taken to avoid radiation of energy during the initial period of frequency variation.

4.1.3 Apart from the initial period of frequency variation, a specific warming-up-time dependent on the class of emission and the service for which the transmitter is intended, may be required before starting transmissions. Due to different applications initial switching-on conditions should therefore be specified in the relevant equipment specification.

5. MEASUREMENT OF MAXIMUM FREQUENCY ERROR OF A TRANSMITTER

5.1 Compliance with the frequency tolerance in the Radio Regulations or with the relevant requirement in the equipment specification is checked by measuring the maximum frequency error of the transmitter as described below.

5.1.1 The value of the maximum frequency error shall be calculated from several series of measurement of the characteristic frequency under any combination of operating conditions. However, to check compliance with the Radio Regulations or the relevent equipment specification, the number of measurements may generally be limited, proceeding as follows:

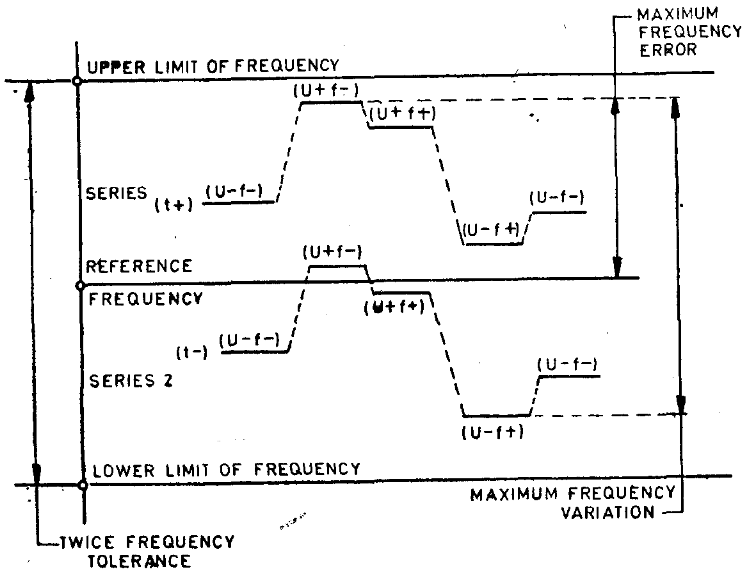
5.1.2 After the frequency determining parts—dials or other means incorporated in the transmitter have been set corresponding to the desired frequency, two series of measurement of the characteristic frequency are performed according to **3** in which the ambient temperature is kept constant at values corresponding to the lower and upper limits specified in the relevant equipment specification. Care shall be taken to ensure that the transmitter has reached thermal equilibrium with its surroundings before making measurements.

5.1.3 During each series of measurement, the primary power supply voltage, the primary power supply frequency and, if required, other operating conditions inherent in the normal use of the equipment are varied sequentially between the specified lower and upper limits and *vice versa*. With respect to varying the operating conditions, it will generally suffice to carry out measurements under any existing combination of humidity and air pressure, provided that they are within the specified limits.

5.1.4 The maximum frequency error is the difference between the reference frequency and the extreme value of the characteristic frequency observed during the two series of measurement.

5.1.5 In Fig. 1 an example is given showing the characteristic frequency for any combination of the extreme values of ambient temperature, primary power supply voltage and primary power supply frequency. In determining the maximum frequency error, the fluctuations due to the operating cycle of the thermostat and occurring during the transition from one combination of parameters to the other (dashed lines) which have been deleted from the figure for the sake of clearness, shall be taken into account.

5.1.6 If required, the frequency drift caused by ageing processes in the crystal(s) and oscillator circuits as described in 7 shall be measured separately. If the influence of frequency drift during the time taken by the measurements cannot be avoided, the time scale in Fig. 1 shall be indicated.



Series 1 — ambient temperature at maximum value t + } the power supply voltage being varied between the limits U — and U +, and the power supply frequency, between the limits f— and f +, respectively

Series 2 — ambient temperature at minimum value t —

Abscissa — time (for convenience the two curves are drawn one underneath the other)

Ordinate — characteristic frequency

Example of curves showing characteristic frequency under various combinations of operating conditions.

FIG. 1 DETERMINATION OF MAXIMUM FREQUENCY ERROR

5.1.7 To take account of additional frequency errors due to the setting procedure of transmitters provided with continuously tunable oscillators, a number of consecutive setting procedures shall be performed according to **8**.

5.1.8 When the transmitter may be operated at more than one frequency, the measurements shall be repeated at other frequencies if this has been specified in the relevant equipment specification.

5.1.9 The maximum frequency errors so determined is expressed in hertz and shall be compared with the frequency tolerance in the Radio Regulations with the relevant (*see* Note 2) in the equipment specification.

NOTE 1 — Setting of the transmitter to the desired frequency may be performed at an arbitrary temperature, except if, according to the relevant equipment specification, the setting procedure is to be carried out at the temperature at which the measurements are made (for example, when the transmitter is to be set to the desired frequency by means of the reading of an incorporated measured instrument).

NOTE 2 — This statement shall preferably be formulated as given in the example below:

Maximum frequency error after a 30 min initial period of frequency variation:

$$\leqslant \pm (5 \times 10^{-6} f + 80 \text{ Hz})$$

in which f is the desired operating frequency expressed in hertz within the range from 4 MHz to 29·7 MHz, for any combination of operating conditions within the following limits:

a) mains voltage :	rated value $\pm$ 5 percent
b) mains frequency :	rated value $\pm$ 2 percent
c) ambient temperature :	$+10°$ C to $+40°$C
d) relative humidity :	$\leqslant$75 percent
e) air pressure :	$8·6 \times 10^4$ Pa — $1·06 \times 10^5$ Pa (N/m^2)
f) Class of service :	Fixed

6. MEASUREMENT OF MAXIMUM FREQUENCY VARIATION OF A TRANSMITTER

6.1 The frequency stability is important to the user because it governs, at the transmitting end, the frequency difference which may arise between transmitter and receiver during a given communication period.

6.1.1 The term frequency stability shall always be used in combination with a certain time duration that depends on the class of emission and the service to be provided. The variations of primary power supply conditions and environmental conditions that are permitted during the given period, and which shall always be within the extreme limits of the operating conditions specified for the frequency tolerance, shall be stated together with the period itself, preferably in the form as given in Note 2 of **5.1.9**.

6.1.2 If desired, the following terminology may be used with respect to the period during which a specific stability is to be maintained.

a) *Short-term frequency stability,*
limited to a period of less than 24 h, for example 1 min, 15 min, 1 h, 3 h, etc.
and, if a specific class of service requires a longer period 24 hours' frequency stability;

b) *Long-term frequency stability,*
covering a number of 24 hours' periods, for example, 2 days, 2 weeks.

6.1.3 In all events, the statement shall include the time period and the variations of the operating conditions that are permitted during this period. These variations are small for short periods; for longer periods they increase and finally they approach the limits of the operating conditions specified for the frequency tolerance.

6.1.4 Compliance with the frequency stability stated in the relevant equipment specification is checked by measuring the maximum frequency variation of the transmitter as described below.

6.2 The measurements may be performed as exmplained in **4.6** for the determination of the maximum frequency error, the operating conditions in this case being varied within the limits pertaining to the frequency stability. From Fig. 1 it follows that the maximum frequency variation is the algebraic difference between the maximum values of the frequency errors observed during the two series of measurement.

6.2.1 As the specified variation of operating conditions generally are relatively small, the measurement may be simplified by proceeding as follows.

6.2.2 The frequency variations resulting from a variation within the specified limits of one of the parameters affecting the characteristic frequency, the other parameters being kept constant, are successively determined for all parameters involved, including the ambient temperature. The absolute values of the frequency variations so determined shall be added to obtain the maximum frequency variation.

6.2.3 Attention is drawn to the fact that, with both methods, the frequency variation may depend on whether the variation of the ambient temperature is chosen in the neighbourhood of the upper limit, or in the neighbourhood of the lower limit of the ambient temperature specified for the frequency tolerance. In this case, more than one series of measurements may be required to obtain the maximum value of the frequency variation.

6.2.4 When the transmitter may be operated at more than one frequency the measurements shall be repeated at other frequencies if this is required in the relevant equipment specification.

6.2.5 The maximum frequency variation determined as explained above is expressed in the hertz and half this value shall be compared with the frequency stability stated in the equipment specification (Note 2).

NOTE 1 — Fluctuations due to the operating cycle of the thermostat may contribute to each of the afore-mentioned frequency variations. In adding the various frequency variations this fluctuation should, however, be taken into account only once.

NOTE 2 — This statement should preferably be formulated as given in the example below:

Frequency stability (over 2 h);
better than $\pm$ ($0{\cdot}5 \times 10^{-6} f + 12$ Hz)

in which f is the operating frequency expressed in hertz after 2 min warming-up time (crystal oven continuously in operation) for any frequency within the range from 7·6 MHz to 29·7 MHz, for the following variations within the limits of the operating conditions stated for the frequency tolerance:

a) mains voltage variation :	$\pm$2 percent of the rated value:
b) mains frequency variation :	$\pm$1 percent of the rated value
c) variation of ambient temperature :	$\pm$3°C
d) variation of relative humidity :	any value within the range

7. FREQUENCY DRIFT (OF A RADIO TRANSMITTER)

7.1 The frequency drift of a transmitter is the variation of frequency in time independent of any other parameter. The effect is usually continuous and irreversible and is the result of ageing processes in the quartz crystals and oscillator circuits of the transmitter. Frequency drift may be considered to be the variation in time of the mean value of the characteristic frequency, after all variations due to short term influences which are usually periodic and reversible, such as diurnal or seasonal variations of ambient conditions, have been eliminated.

7.2 Ageing processes in the quartz crystals may cause a drift towards higher frequencies or towards lower frequencies, the intensity decreasing with time. Ageing processes in the oscillator circuit itself may cause a drift in the reverse direction occurring simultaneously or after a certain period and causing fluctuations in the frequency drift in the very long run. The determination of this effect is therefore commonly beyond the normal programme of measurements on radio transmitters for which reason no exact definition is given and no method of measurement is specified.

7.3 In this connection, it is important to note that maintenance of the characteristic frequency within the limits given by the frequency tolerance, the transmitter being in actual service, still requires periodic

checks and adjustments of the oscillator, for example by comparison with standard frequency emissions.

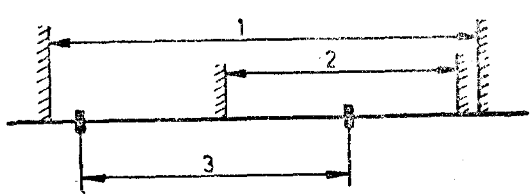
8. MEAN FREQUENCY SETTING ERROR AND FREQUENCY RESETTING ACCURACY

8.1 When a transmitter is set to a particular frequency, the characteristic frequency obtained will generally differ from the desired reference frequency.

8.1.1 In transmitter provided with continuously tunable oscillators including synthesizers, permitting the frequency to be set, either manually or automatically, within a certain frequency range, the frequency difference observed, called "frequency setting error", may be due to the calibrating error of dials or other means indicating the frequency, or to frequency errors of an auxiliary oscillation that might be used for setting and checking the operating frequency.

8.1.2 The setting error is not constant; during a series of resetting procedures it may vary within a certain range due to, for example mechanical imperfections of the frequency determining parts. Therefore, a mean frequency setting error is defined, being the difference between the arithmetic mean of the characteristic frequencies obtained after a number of consecutive setting procedures and the reference frequency.

8.1.3 The frequencies so obtained are situated around the arithmetic mean; the departure of the characteristic frequency from this arithmetic mean, expressed as a standard deviation, or in short, the "frequency resetting accuracy" may be considered as a measure of the accuracy with which a certain frequency may be reproduced. An explanatory drawing of the definition of frequency setting error and frequency resetting accuracy is given in Fig. 2.



Reference frequency f_r

Arithmetic mean f of all characteristic frequencies f_i

1 = region in which the n characteristic frequencies f_i fall
2 = twice the frequency resetting accuracy [$2\,S\,(n)$]
3 = mean frequency setting error

FIG. 2 MEAN FREQUENCY SETTING ERROR AND FREQUENCY RESETTING ACCURACY

8.1.4 The measurement is to be carried out after the specified initial period of frequency variation has elapsed. The operating conditions shall be within the specified limits and be substantially constant during the measurements so as not to have any appreciable influence on the generated frequency.

8.1.5 Under these conditions, a specified number (at least 10, and preferably 15) of setting procedures is performed in rapid succession, the frequency being measured according to **4.4** after each setting procedure.

8.1.6 The frequency resetting accuracy shall be evaluated as standard deviation from the formula:

$$S_{(n)} = \sqrt{\frac{1}{n} \sum_{i=1}^{n} (f_i - \bar{f})^2}$$

where

n = number of measurements;

f_i = value of frequency, of any individual measurement;

$\bar{f}$ = arithmetic mean of all values of f_i :

$$\bar{f} = \frac{1}{n} \sum_{i=1}^{n} f_i \text{ ; and}$$

$S_{(n)}$ = resetting accuracy expressed in the same units as f_i.

The mean frequency setting error amounts to the difference between $\bar{f}$ and the reference frequency.

The maximum frequency setting error may be derived from Fig. 2.

NOTE — Attention is drawn to the fact that the mean frequency setting error and the maximum frequency setting error principally depend on the operating conditions. For different values of the ambient temperature, power supply voltage, etc, different values of the setting errors will be found. This applies to a much less extent to the frequency resetting accuracy.

(*Continued from page* 2)

Panel for Transmitters, LTDC 20/P6

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